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REMOTE SENSING OF VEGETATION AND SOIL MOISTURE

National Aeronautics and Space Administration
Goddard Space Flight Center
Contract NAG 5-141

SEMI-ANNUAL REPORT

covering the period

September 1, 1982 - February 28, 1983

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REMOTE SENSING OF VEGETATION AND SOIL MOISTURE

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Semi-Annual Progress Report

This is a report on the progress that has been made in the study for remote sensing of vegetation and soil moisture under the sponsorship of NASA Contract NAG 5-141 during the period of September 1, 1982 - February 28, 1983. During this period we have: (1) solved the problem of microwave scattering from periodic surfaces using a rigorous modal technique; (2) studied the combined random rough surface and volume scattering effects; (3) investigated the anisotropic effects of vegetation structures; (4) applied the strong fluctuation theory to the study of electromagnetic wave scattering from a layer of random discrete scatterers; and (5) studied the scattering of a plane wave obliquely incident on a half space of densely distributed spherical dielectric scatterers with quantum mechanical potential approach.

The problem of microwave scattering from periodic surfaces is solved by using a rigorous modal technique which conserves energy, obeys reciprocity, and takes into account the multiple scattering and shadowing effects. The theoretical results have been applied to the calculation of the radar backscattering cross sections in active remote sensing and the brightness temperatures in passive remote sensing, and used to match field data from soil moisture measurements. The angular behavior of the brightness temperatures has been explained with the threshold phenomenon by considering the appearance and disappearance of the various Floquet modes.

The combined random rough surface and volume scattering effects have been studied by employing a Gaussian random surface and applying the small perturbation methods which is modified with the use of cumulant techniques. The rough surface effects are incorporated into the radiative transfer equations by modifying the boundary conditions for the intensities. The radiative transfer equations are then solved numerically using the Gaussian quadrature method and the results are illustrated and compared with experimental data.

The anisotropic effects of vegetation structures are investigated and the theoretical results are used to match experimental data. The azimuthally anisotropic behavior of the measurement result is attributed to the orientations of the vegetation stalks which were laid on the ground during the field measurements. The effect of the soil moisture on the brightness temperature measurements from the wet and dry corn stalks has been clearly identified.

The strong fluctuation theory is applied to the study of electromagnetic wave scattering from a layer of random discrete scatterers. The singularity of the dyadic Green's function is taken into account in the calculation of the effective permittivity functions. The correlation functions for the random medium with different scatterer constituents and size distributions are derived. Applying the dyadic Green's function for a two layer medium and using the bilocal and distorted Born approximations, the first and the second moments of the fields are calculated.

The scattering of a plane wave obliquely incident on a half space of densely distributed spherical dielectric scatterers is studied with quantum mechanical potential approach. The quasi-crystalline approximation is applied to truncate the hierarchy of multiple scattering equations and Percus-Yevick

result is used to represent the pair distribution function. While results at high frequencies are calculated numerically, closed form solutions are obtained in the low frequency limit for the effective propagation constants, the coherent reflected wave and the bistatic scattering coefficients.

Publications

The work performed under the sponsorship of NASA Contract NAG 5-141 during the period of MARCH 1, 1981 - February 28, 1983, has been published in the categories of:

- A. Journal Articles
- B. Conference Papers
- C. Manuscripts

A. Journal Articles

- A1 L. Tsang, M. C. Kubacsi, and J. A. Kong, "Radiative transfer theory for active remote sensing of a layer of small ellipsoidal scatterers," Radio Science, 16, no 3, 321-329, May-June 1981.
- A2 R. T. Shin and J. A. Kong, "Radiative transfer theory for active remote sensing of a homogeneous layer containing spherical scatterers," J. Appl. Phys., 52, 4221-4230, July 1981.
- A3 F. Vallese and J. A. Kong, "Correlation function studies for snow and ice," J. Appl. Phys., 52, 4921-4925, August 1981.
- A4 S. L. Shuang and J. A. Kong, "Scattering of waves from periodic surfaces," Proc. IEEE, 69, no. 9, 1132-1144, September 1981.
- A5 L. Tsang, J. A. Kong, and R. W. Newton, "Application of strong fluctuation random medium theory to scattering of electromagnetic waves from a half-space of dielectric mixture," IEEE Trans. Ant. Prop., AP-30, no. 2, 292-302, March 1982.
- A6 S. L. Chuang and J. A. Kong, "Wave scattering from a periodic dielectric surface for a general angle of incidence," Radio Science, 17, no. 3, 545-557, May-June 1982.
- A7 J. A. Kong, S. Lin, and S. L. Chuang, "Thermal microwave emission of periodic surface," IEEE Transactions on Geoscience and Remote Sensing, to be published.
- A8 S. L. Chuang and J. A. Kong, "Wave scattering and guidance by dielectric waveguides with periodic surface," Journal of the Optical Society of America, to be published.

- A9 Y. Q. Jin and J. A. Kong, "Strong fluctuation theory for electromagnetic wave scattering by a layer of random discrete scatterers," IEEE Transactions on Antennas and Propagation, to be published.
- A10 Y. Q. Jin and J. A. Kong, "Passive and active remote sensing of atmospheric precipitation," Applied Optics, to be published.

B. Conference Articles

- B1 J. A. Kong, R. T. Shin, and S. L. Chuang, "Active and passive microwave remote sensing of earth terrain," IEE Second International Conference, University of York, U.K., April 13-16, 1981.
- B2 S. L. Chuang and J. A. Kong, "Remote sensing of dielectric media with periodic rough surfaces," 1981 International Geoscience and Remote Sensing Symposium, Washington, DC, June 8-10, 1981.
- B3 M. A. Zuniga and J. A. Kong, "Mean dyadic Green's function for remote sensing of a two layer random media," 1981 International Geoscience and Remote Sensing Symposium, Washington, DC, June 8-10, 1981.
- B4 R. T. Shin, S. L. Chuang, and J. A. Kong, "Radiative transfer theory for microwave remote sensing of an inhomogeneous medium with rough surfaces," URSI Meeting, Los Angeles, CA, June 15-19, 1981.
- B5 J. A. Kong, R. T. Shin, F. J. Valles, S. L. Chuang, and J. K. Lee, "Random medium model for microwave remote sensing of earth terrain," URSI Meeting, Los Angeles, CA, June 15-19, 1981.
- B6 J. A. Kong, "Theoretical models for microwave remote sensing of vegetation and soil moisture," AgRISTARS Symposium, Houston, Texas, December 1-2, 1982.
- B7 J. A. Kong, S. L. Lin, S. L. Chuang, and R. T. Shin, "Remote sensing of soil moisture and vegetation," URSI Symposium, Boulder, Colorado, January 5-7, 1983.
- B8 R. T. Shin and J. A. Kong, "Thermal microwave emission from a scattering medium with rough surfaces," URSI Symposium, Boulder, Colorado, January 5-7, 1983.
- B9 Y. Q. Jin and J. A. Kong, "Mie scattering of electromagnetic waves by precipitation," Optical Society of America Topical Meeting on Optical Techniques for Remote Probing of the Atmosphere, Lake Tahoe, Nevada, January 10-12, 1983.
- B10 L. Tsang and J. A. Kong, "Scattering of electromagnetic waves from a half-space of densely distributed dielectric scatterers," IEEE/APS Symposium and URSI Meeting, Houston, Texas, May 23-26, 1983.

- B11 L. Tsang and J. A. Kong, "Theory of microwave remote sensing of dense medium," IEEE/GRS Symposium and URSI Meeting, San Francisco, September 1983.

C. Manuscripts

- C1 S. L. Chuang and J. A. Kong, "Radiative transfer theory for thermal microwave emission from random medium with rough surfaces," to be published.
- C2 J. R. Wang, J. C. Shiue, S. L. Chuang, and M. Dombrowski, "Thermal microwave emission from vegetated fields: A comparison between theory and experiment," to be published.
- C3 R. T. Shin and J. A. Kong, "Emissivity of a two-layer random medium with anisotropic correlation function," Technical Report No. EWT-RS-41-8303, MIT, 1983.